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A Study on the Characteristics of Improvement in Filtration Performance by Dust Precharging

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Abstract−A hybrid dust-collector combining electrostatic charging with fabric filtration was developed and its performance characteristics were evaluated. Charged particles build porous dendritic structure on the filter surface by electrostatic attraction, increasing the collection efficiency of dust particles and reducing the pressure drop through the deposited dust layer and filter media. The cleaning performance of the dust layer is improved because the dendritic structured dust layer may be removed more easily by pulse jet cleaning flow. The results of the experiment showed a reduction of fine particle emission by 37% and 13% energy saving by precharging dust particles before filtration.

Key words: Fabric Filter, Electrostatic, Precharge, Pressure Drop, Collection Efficiency

INTRODUCTION

The bag filter is the most widely used air pollution control unit in industry due to its stability of operation and high efficiency [McIlvaine, 1995]. Although its demand is still going up, the fabric filtration method has some disadvantages such as low efficiency for fine dust particles and high operation cost caused by high pressure drop. Especially, fine dust particles cause pore blockage of fabric filter, increasing the pressure drop across the filter and shortening its life.

In order to solve these problems, this research aimed to develop a hybrid filtration system combining electrostatic dust precharging with fabric filtration for lowering the pressure drop and dust emission of fabric filter.

There are some dust charging mechanisms such as static electrification, diffusion charging, and field charging. The last two require high concentrations of unipolar ions. Because of the mutual repulsion and high electrical mobilities of those ions, their lifetime is short. To resolve this problem, corona discharging was commonly introduced to continuously produce unipolar ions at high enough concentration to be useful for dust charging [Hinds, 1999].

A dust charged in corona discharge fields is usually captured on the surface of filter media and forms a porous dendritic structured layer, because electric fields tend to be concentrated on the end point of dust particles captured previously [Park et al., 1999; Yoa et al., 2001]. The dust layer formed in that manner makes pressure drop across the filter low, and collection efficiency high due to reinforced collection mechanism with electrostatic force [Lamb, 1981].

EXPERIMENTAL

1. Dust Precharger

The dust precharger for charging dust particles consists of multiple saw type discharge electrodes and plate type ground electrodes with a space of 30 mm between each electrode as shown in Fig. 1. This precharger was designed to produce the non-pulsed negative corona for effective and stable operation.

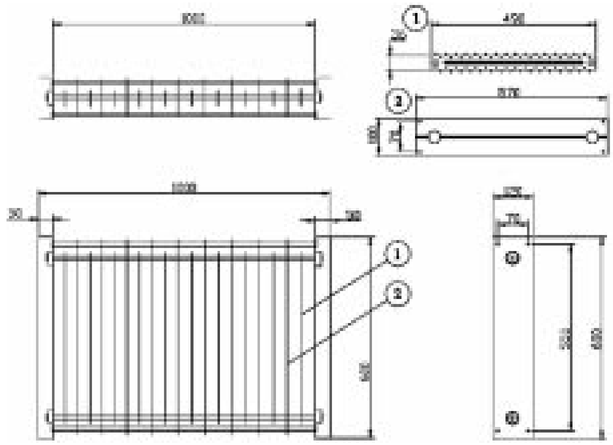

Fig. 1. Dust precharger.

2. Test Filter

A test filter was manufactured by coating the filter surface with porous acrylic polymer for the surface filtration. Nonwoven polyester fabrics were used as supporting materials. A total of 16 bag filters of 156 mm in diameter and 2,500 mm in length are installed in the test chamber.

3. Experimental Setup

The experimental setup consists of a dust supplying and dispersing part for controlling dust concentration, a precharging part for dust charging, a fabric filter unit (baghouse) for evaluating the filter performance, an air suction and flow controlling part, compressed air supply system for filter cleaning, and data acquisition unit (Fig. 2).

The fabric filter unit has a pulse-jet cleaning module for filter cleaning. The maximum flow capacity of the fabric filter unit is 60 m^3/min.

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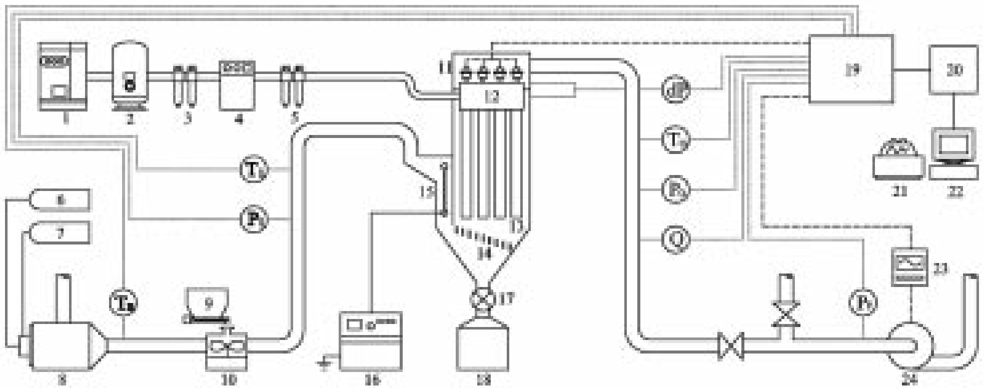

Fig. 2. Schematic diagram of experimental setup.

1. Air compressor	7. LP gas	13. Bag filter	19. Main control box
2. Air tank	8. Hot gas generator	14. Ladder vane baffle	20. A/D converter
3. Pre-filter	9. Test dust feeder	15. Dust ionizer	21. Printer
4. Air dryer	10. Dust disperser	16. High voltage generator	22. Computer
5. Final filter	11. Solenoid valve	17. Rotary valve	23. Phase inverter
6. Fuel oil	12. Pulse air header	18. Portable dust box	24. Exhaust fan

4. Experimental Procedure

In order to evaluate the effect of dust precharging on the performance of the bag filter, the pressure drops and dust collection efficiencies of bag filters were measured with uncharged and charged dust particles, respectively. The mass concentrations and size distributions of dust particles at the inlet and outlet were measured by using an Aerosizer (Mach-LD, API).

The lime particles which flew off during crushing and conveying process of limestone were used as test dust. The dust particles were fed continuously into the inlet duct with the mass concentration of 180 mg/m^3 by volumetric screw feeder.

Fig. 3 shows the relationship between the discharge current of precharger and the amount of particle charge for lime dust. The amount of dust charge was measured with Aerosol Electrometer (3068A, TSI Inc.). Since the discharge current increased very rapidly above −8 kV, whereas the amount of dust charge increased no more, the applied voltage was kept as −8 kV for the dust charging condition.

The overall test conditions are summarized in Table 1.

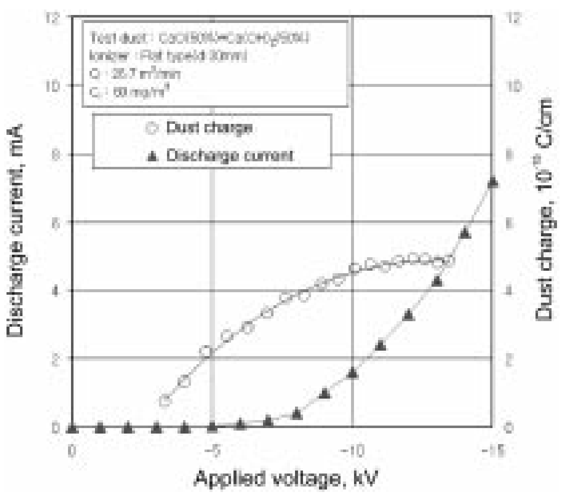

Fig. 3. Discharge and dust charge characteristics of dust precharger.

Table 1. Test conditions

Test dust	Lime dust
Filtration velocity (V_f)	1.36 m/min
Inlet dust concentration (C_i)	180 mg/m^3
Temperature (T_i)	Ambient condition
Applied voltage (when precharged)	−8 kV
Test filter	L-MEMFIL™
Cleaning onset base (ΔP of filter)	100 mmH_2O
Cleaning air pressure	5 kg$_f$/cm^2
Cleaning duration	120 msec

RESULTS AND DISCUSSION

1. Pressure Drop

Fig. 4 shows the pressure drop across the filter for the case of charged and uncharged dust particles. As shown in this figure, increasing rate of the pressure drop is reduced by 35% in the charging condition than in the uncharging condition.

Also, the average cleaning interval is prolonged about twice when the particles are charged. This may be caused by the attachment of dust to the wall of filter casing and by the formation of a porous dust layer with dendritic structure at the filter surface due to the electrostatic force between charged particles.

Residual pressure drop after filter cleaning is about 24% lower for the charging condition than for the uncharging condition. This is because charged fine particles are agglomerated with dendritic structure by the electrostatic force, which prevents clogging the pores of filter media.

Since the filter performances such as cleaning interval and residual pressure drop are directly related with filter lifetime, it is reasonable from this result that the filter lifetime can be extended about twice as much by applying electrostatic dust charging method to the fabric filter system.

2. Dust Collection Efficiency

Fig. 5 shows fractional collection efficiencies for the case of

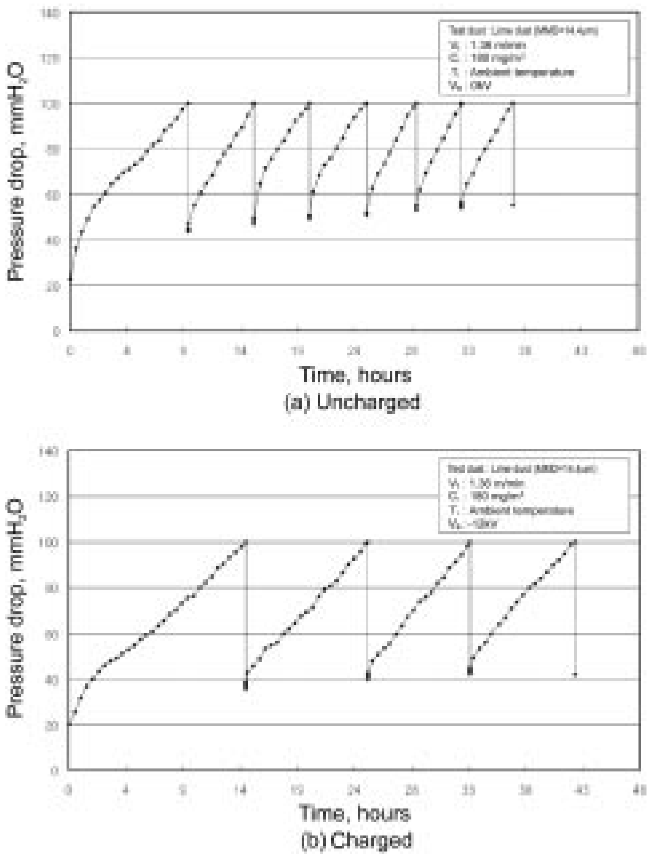

Fig. 4. Pressure drop of bag filter.

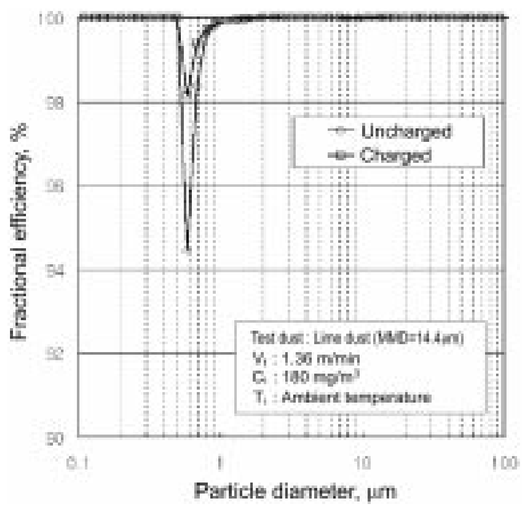

Fig. 5. Fractional dust collection efficiency.

charged and uncharged dust particles. For both cases, collection efficiency has a minimum value at a particle size of around 0.6 μm. The collection efficiency for the charged particles is about 4% higher than for the uncharged ones. This is a significant improvement, considering the fact that the submicron particles are most hazardous to human health.

The total penetration of dust particles smaller than 2.5 μm in diameter (PM2.5) for the charging condition is 37% lower than for the uncharging condition. It is noteworthy that the improvement of dust collection efficiency by electrostatic charging is effective especially for the fine particles.

The overall dust collection efficiencies are higher than 99.99%, and dust penetrations are extra low for both conditions. However, the overall dust penetration through the filter media for the charging condition is reduced to 97% of that for the uncharging condition.

3. Filter Performance

With quantitative measures of a balance between collection efficiency and pressure drop of filters, filter performance value is frequently estimated. This value is defined by the following Eq. (1).

$$FP = -\frac{\log(P[\%]/100)}{\Delta P[mmH_2O]} \times 100 \qquad (1)$$

Here, P is the dust penetration and ΔP is the pressure drop across the filter. The higher the filter performance value, the higher the dust collection efficiency and the lower the pressure drop of filters.

Fig. 6 compares the filter performance value for the charging and uncharging conditions. The filter performance value for the charging condition is 32% higher than that for the uncharging condition. This is because both the cleaning and the collection efficiency of

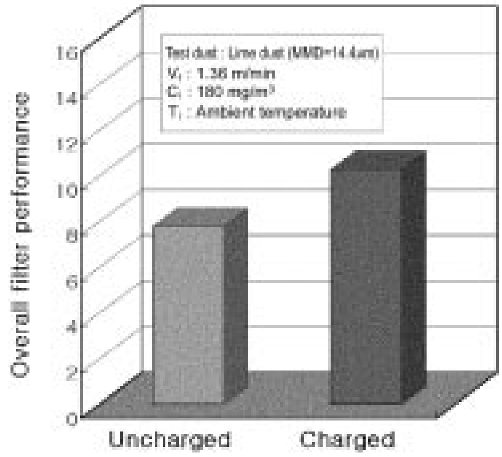

Fig. 6. Filter performance.

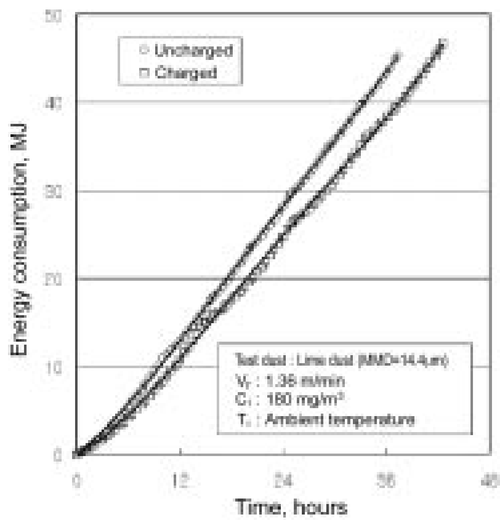

Fig. 7. Total energy consumption.

the filter are improved by dust charging.

4. Energy Consumption

Fig. 7 compares the total energy consumption for the charging and uncharging conditions. The total energy consumption is the sum of the energy required for suction of gas, that for air compression necessary to filter cleaning and that for dust charging. The energy for gas suction was calculated by using the measured pressure drop, filter area, and gas flow rate. The energy for filter cleaning was obtained by the estimation of the air compression as a polytropic process to compensate the pressure deviation between just before and after cleaning [VanWylen and Sonntag, 1986]. Precharging energy was calculated by using the voltage and current applied to the precharger. The equations used to calculate the energy consumption are as follows.

$$E_{fan}=\Delta P(t)\cdot A_{filter}\cdot t \tag{2}$$

$$E_{comp.}=N\cdot\frac{(P_2-P_1)V_{header}}{(1-n)} \tag{3}$$

$$E_{charge}=V\cdot I\cdot t \tag{4}$$

Here, ΔP is the pressure drop of the filter, A_{filter} is the filtration area, t is the operating time, N is the number of cleaning, P_1 and P_2 are the pressure of reservoir just before and after cleaning, respectively, n is the exponent for polytropic process, V_{header} is the volume of reservoir, V is the applied voltage, and I is the applied current.

From the calculation, the energy for gas suction was the highest and the relative portion of the energy for filter cleaning increased as the cleaning process proceeded. As shown in the figure, the case of dust charging consumed 13% less total energy, although additional energy was required for electrostatic dust charging and more frequent filter cleaning per unit time.

Fig. 8 shows the summarized results of these experiments. In this figure, the values represent the relative filter performances for the charging condition, supposing those of the uncharging condition as 1.

In this figure, the cleaning frequency is a reciprocal of an average cleaning interval of the whole operation time. And the rate of ΔP rise is a value of a average pressure drop rise from residual pressure drop to cleaning onset point (100 mmH_2O) divided by average cleaning interval.

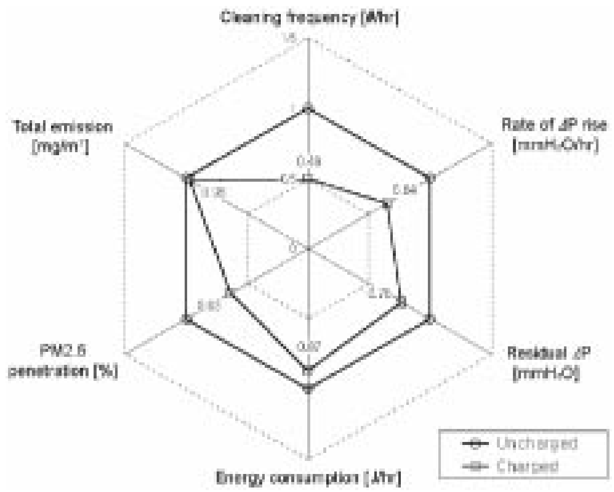

Fig. 8. Comparison of results.

From this comparison, it can be concluded that the dust precharging does a great deal for the improvement of overall filter performance, especially for the extension of cleaning interval and the increment of the collection efficiency of fine dust particles.

CONCLUSIONS

A hybrid dust-collector combining electrostatic charging with fabric filtration was developed and its performance characteristics were evaluated.

For the dust charging condition, the average cleaning interval was prolonged about twice as much and the residual pressure drop after filter cleaning was reduced by 24% than that for the uncharging condition. This is because the dust attaches to the wall of the filter casing and forms a porous dust layer with dendritic structure on the filter surface due to the electrostatic effect of charged particles.

Since the filter performance such as cleaning interval and residual pressure drop are directly related with filter lifetime, it is reasonable that the filter lifetime can be extended about twice as much by applying electrostatic dust charging method to the fabric filter system.

The improvement of dust collection efficiency by electrostatic charging is so effective especially for the fine particles as to lower the penetration of PM2.5 for the charging condition by 37% compared with that for the uncharging condition.

The case of dust charging consumed 13% less total energy although additional energy was required for dust charging to decrease in the residual pressure drop and the number of filter cleanings per unit time.

NOMENCLATURE

A_{filter}	: filtration area [m^2]
E_{charge}	: energy for corona discharge [J]
$E_{comp.}$	: energy for air compression [J]
E_{fan}	: energy for gas suction [J]
I	: current applied to dust precharger [A]
N	: number of filter cleanings [-]
n	: exponent for polytropic process [-]
P	: dust penetration [%]
P_1	: air pressure in reservoir just before cleaning [Pa]
P_2	: air pressure in reservoir just after cleaning [Pa]
FP	: filter performance value [-]
ΔP	: pressure drop of filter [mmH_2O]
t	: operating time [sec]
V_{header}	: volume of air reservoir (header) [m^3]
V	: voltage applied to dust precharger [V]

REFERENCES

Hinds, W. C., "Aerosol Technology," Wiley (1999).

Lamb, G. E. R. and Costanza, P. A., "Electrical Stimulation of Fabric Filtration," *Textile Research Journal*, **51**, 389 (1981).

McIlvaine, R. W., "Fabric Filter Market Rises, Replacing Precipitators," *Environment Solutions*, **8**(11), 21 (1995).

Park, Y. O., Lim, J. H., Kim, S. D. and Choi, H. K., "Development of High Efficiency Hybrid Type Dust Collector Combining Electrostatic Charging with Membrane Filter," Final Report of Clean Energy Development Project, Ministry of Commerce, Industry & Energy of Korea (1999).

VanWylen, G. J. and Sonntag, R. E., "Fundamentals of Classical Thermodynamics," Wiley (1986).

Yoa, S. J., Cho, Y. S., Choi, Y. S. and Baek, J. H., "Characteristics of Electrostatic Cyclone/Bag Filter with Inlet Types (Lab and Pilot Scale)," *Korean J. Chem. Eng*., **18**, 539 (2001).